How Do Atomistic Models Act on the Understanding of Nature in the Young Person?

From Chapter 12, *Fields, Rays, Atoms,* a book on 11th grade Physics

By

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After his introduction about the issues surrounding bringing science in a way that depends heavily on the model-based approach common in many physics books, Dr. Mackensen explores how we might do it another way and why. We invite comments on how you have tried to address these issues and hope to stimulate dialogue on this complex but crucial issue. — J. Petering.

Pro and con models in teaching

The abyss between naive experience and quantum theory (i.e. what scientists may think) is of course bridged in teaching—as is well known—with so called models; i.e. with visual, easy to follow simplifications. For the time being we are going to lay aside the epistemological and culturally critical doubts outlined so far, in order to consider the models—this central conceptual form of contemporary education—once more from a different side—in the context of teaching.

Educational consequences of model-thinking

The main question in regard to thinking in visual models surely is this: To which spiritual forces are they giving rise in the student as they strive to understand the world as it manifests itself to the senses?

The purpose of a model is always—as with any kind of explanation—to trace back the unknown to what is already known. In model-thinking however, those things known are chosen very one-sidedly. For in the beginning it is mostly concerned with the idea of primitive things (particles) which interact mechanically or maybe electrostatically. The real macroscopic fields of phenomena included in these ideas (e.g. mechanics) are far removed from the individual phenomena which they purport to explain. Thus with the mechanics of rigid bodies, for instance, the original (phenomenological) impression is far removed from chemical reactions: here we have impenetrability in space and permanence—there we have inner penetration of substance, disappearance and new emergence. The causal connection between the two, e.g. through applying the laws of impact to the reaction of gaseous molecules, normally is in no way considered to be a problem, rather a triumph.

Another example: One imagines the circular path of the electron to be maintained through the equilibrium between electric attraction and centrifugal force. Such an equilibrium is known from the planetary movements. The path of the electron therefore is a model, a visual representation, that is according to the pattern of macroscopic conditions. Since the macroscopic ideas —in our example the equilibrium in the paths of planetary bodies (satellites)—are very widely independent from their absolute dimensions, they were thought fit to be projected into atomic dimensions. This projection however, when it is made more and more concrete, leads to contradictions as was described above. For this reason in school book-literature it is usually said: a model only has as much value as there is clear awareness of the limits of its application. This surely means nothing less than—through using the model—giving up to penetrate into the whole of reality and to form concepts that can be applied to the perceptible whole. Moreover, through the model one is trapped in the particular segment of reality selected for interpretation. This is why the model is formed: the thing as a whole, as it appears in its own sphere, is not mastered by one's thinking and is, therefore, transplanted into spheres where it appears more clearly, i.e. mechanistically. From the opposite point of view this would be the very argument for the models (for their economy). In my view it is a call for a different approach.

Thus model-based thinking does not strengthen those spiritual forces in the human being through which he actively wants to familiarize himself with the world as a whole as it appears to the senses, in order to fathom, and work it through towards individually formed concepts—that is all that which could later on give confidence in science to the lay man. Instead it increases the dependence on changing questions of a specialist, kind and it trains a formal faculty of imagination and the deductive observation of isolated phenomena. The reason which model-based thinking is so tempting for contemporary man is because it limits soul activity down to the cognitive (intellectual) aspect which leads to an outer command over nature and which does not press for a deeper qualitative penetration of sense-realities. It confronts the latter only through recording (perception as signal) and through hypothesizing (superimposing a model). This is in accordance with an already existing preference of modern man and it thereby gains in popularity. Somewhat pointedly: In school teaching, models mostly lead away from the original self-discovering activity of perception and of thinking, away from the individual laborious path to clear undimmed experience; they are escalators to the heights of incompletely understood abstraction.

A second question must be: With how much understanding for the true facts of atomic theory does model-based thinking leave us at the end of schooling? Models in the early syllabus often project categories borrowed from the world of senses, i.e. categories of classical physics, into atomic structures. This bypasses—as outlined above—the actual nature of quantum type of phenomena and therewith the nature of atomic theory altogether—and after some steps it always leads to contradictions. Models want to shortcut what on principle cannot be cut short without writing off the most important part. But the most important part of wave mechanics and of the theory of relativity after all is that they *invalidate* naive (ontological) materialism. The premature models on the other hand *validate* the latter.

If one follows the contemporary premature introduction of model-based ideas, the students will hugely retain the *ancient* concept of the atom! To them the modern discoveries appear only as complication instead of utter invalidation. This development of thinking stagnates at the level of Ancient Greece. In this way, then, a "scientific world conception" arises through model-based thinking, as we had to describe it in its whole wretchedness at the outset.

An optimal factual understanding of the true facts in the area of atomic theory is therefore not achieved for the present and mostly it is even thwarted. For any later understanding is shifted through thinking—habits and cognitive debris—that is all that remains; all this will have to be cleared out later on.

Can models be justified as efficiency-increasing teaching aids?

In spite of all these shortcomings, the models could, as far as economy of learning is concerned, be considered to be so advantageous that one would still want to use them in teaching. In that case the impact of the above objections is usually softened by emphasizing (like all "progressive" specialist teachers and textbooks) the limits to each model. To do more than that is not considered feasible.

Here in particular the observation of the development of thinking in the adolescent can prove something different. Even if the teacher considers himself to be a Nominalist in the sense of scholastic categories—he does not come across that way in this area, as outlined at the outset. At least the younger student remains realist. Explanations of real phenomena he takes to be real! He will not understand that "limit" here means something much more complicated, that is, something to do with epistemology. The "limit" of validity after all means (generally speaking) that somewhere there is factual validity. However, the scope of validity of visual models in a real sense is zero. The model is (as an element of Beingness) nothing more than the phenomena that give explanations are without the model. In suggested curricula for high schools it is stated that "a model can never be wrong or outdated" since it is only supposed to summarize a pre-arranged selection of empiric facts for the purpose of simple imaginability and can therefore only in some cases be unsuitably arranged. If now at the same time it is said that the model always contains only one part of the truth, then the previously rejected ontological substitute is unintentionally being admitted. Going beyond the mere impression of the senses, the model is supposed to produce explaining, substantiating truth—up to certain limits, it is true, and in piecemeal fashion, but truth nevertheless, and does so via the path of model-based thinking.

The strong influence of the models upon the direction of ideas in the young human being stems from the seeming realism of these conceptions. This does not just arise within the young human being as his own misconception (lacking the faculty to grasp the epistemological change of aspects) but lies in the very method of approach, in the atmosphere of the teacher. For it is true, the models are consciously being introduced as convention, i.e. as Nominalistic conceptual interconnections. In spite of that however they are chosen on the grounds of a possible further shaping and extension in the direction of "true" quantum mechanics. Out of this misconceived aim realism arises, which however cannot be maintained on closer scrutiny of the nature of quantum theory—as already shown.

Borrowing in this way from the supposed realism (which quantum mechanics has "proven") on the part of the actually Nominalistic models is on the whole an ontological substitute of matter, and it is the effective device to bait the student's existing need to unfold the world, in order to trap it in a mechanistic ideology—without most teachers being aware of this. Thereby the ideology outlined does not only arise, but at the same time promotes the belief that it is scientifically proven for good. As with every ideology, it is then felt to be progressive and liberating, fundamentally and in essence illuminating, and irrefutable for all times!

In spite of all this there might be the odd practical-minded teacher who still prefers the models for reasons of learning—economy. After all, as one author says, we are "forced to already introduce a usable atomistic model in the intermediate grades. For the enormous amount of facts which the beginner cannot possibly survey not only has to be organized but must also be 'understood,' i.e. mentally digested."

A related argument is often raised: Model-based considerations today are the only way of working and thinking that links together the whole of chemistry and science. Any curriculum which bypasses this finds itself spiritually on another plane! This opinion can only be invalidated by developing a factual chemistry syllabus that can do without the models in, say, the four high school grades. This has now been done and has been tested in the classroom within a didactic research project.

It is to be shown in further practical application that it is possible to work and to learn with such an approach in an educationally purposeful way and benefiting the subject at the same time; and apart from this that the later transition to models and formulae will still lead to the specific aspects of chemistry in a sufficiently encompassing way. Then in the end the demands of education (as well as of the subject) would have the right balance. The opponents of any re-thinking in the higher classes which would therewith become necessary have to be told in the words of Wagenschein: "I can think of no reason why the schools should not only fail to encourage but even explicitly prevent any re-thinking, which after all is thinking based on facts." The decision to pursue a phenomenological education on an epistemologically sound base (i.e. without plain phenomenalism on the one hand, and without animism on the other)—even if not fully developed—is the only thing that can be put against the deplored deficiencies in the naïve attitudes towards nature and science.

How can a late introduction of the models be realized today?

After the foregoing criticism of the early introduction of models, here is a glance at a possible late introduction of these theories, which, of course, are indispensable for the understanding of contemporary science.

Sketch of a curriculum in the sense of a comprehensive school ('Gesamtschule')

The concept of a syllabus in the sense of the thoughts outlined here, e.g. for chemistry (parts of physics are thereby also transformed and integrated), generally makes cuts in the volume of specialist teaching material—for the benefit of a penetration from the point of more mechanics, which otherwise is in most cases not offered and which includes demanding experiments. The whole of atomistic theory is introduced, even if late, but then on the basis not only of modern but of actually constituting conceptions of the wave-particle dualism. This tendency in the didactics of chemistry (from a purely specialist approach) also shows up elsewhere. The well-known quantum-chemist Preuss calls the confusion of rules and simple model-based descriptions ("electron-bowling") a first stage, which was useful (and partly still is) but which does not lay hold of the actual facts.

It is not the point of the approach followed here to declare the classic atomistic theory or the models usually used in teaching as being fundamentally questionable and to scrap them. What is the point is that the teacher introduce these model-based structures concurrently with the right forms of their conceivability—or at least to discuss this. Otherwise the conceptions of naive (and maybe even of didactic) materialism as it was deplored in the above, are being consolidated. The latter of course implies that the atomic structures be essentially within reach of the comfortably visual ideas of everyday or other scientific experience—the ideas of place, time, mass and occupation of space, as well as tangible identity. Such a misconception nowadays is always at hand considering popular literature. The atomic theory of earlier centuries also succumbed to it. This misconception can only be avoided if the atomic theory is developed not historically or in a positivistic triumphant way—"how marvelously far we've come"—but as it was from its epistemologically questionable other end.

The wave-particle-dualism of matter here is the basic conceptual formation. For the students, however, to gain such an understanding in an undogmatic way can only come about through important, if possible personally conducted experiments.

An appropriate experiment however, e.g. the diffraction and interference of electrons, is only comprehendible with a wide background-knowledge of physics—at its earliest probably in class 12. It seems neither possible nor educationally sensible to inject such specific preparatory knowledge earlier, say in class 9. For an important characteristic of atomic phenomena is the very fact that they are understood and have meaning not as isolated experimental statements but only at a later stage on the conceptual base of all the different parts of the whole of physics. Thereby advantage is taken of the fact (which is also a demand) that one teaches within the framework of a comprehensive school of at least 12 classes as in Waldorf school, i.e. where the students rarely leave before class 12.

Therefore, the task of waiting with model-based interpretations until say class 11 arises and today is widely felt to be an impossible one. To be able to do chemistry appropriate to the age up to this point, a new orientation and additional training of teachers becomes necessary; also in related subjects.

The position of this type of didactics in relation to a comprehensive school is yet to be examined. If the student's faculty of thinking and judgment can successfully be kindled by directly taking in the phenomena,* and if the students themselves can be made to feel that their mental capacities are thereby growing, then, for a start, all the theoretic, dogmatic ballast can be suppressed, which today—in form of the crude conceptions of the particle—

is thrown at the children from all sides by the media. If therefore the syllabus in classes 8, 9 or 10 does not move within the superimposed awareness of the problem but instead, if in experiment it meets always anew a reality which at first is not systematized, then the promise of the comprehensive school can be fulfilled in this way—and only in this way: The student of the lower school can become active side by side with the student of the upper school in that he observes, describes, compares and in that he receives and reports on the further reaching implications, which are developed more with the student of the upper school—and both are making progress. It therefore is not so much the delaying of the models which makes up the syllabus of a comprehensive school, but rather that which is done in place of the models and which replaces them for a time.

* The term phenomenology (phenomenological) today is generally not used in the sense that is meant here, because it is not known. One will grasp what is meant here, when one gradually learns to differentiate between "phenomenal" and "phenomenological." The following definition may be a first indication:

- A phenomenon (as is well known) is different from a perception (sense experience). It already is an integrating, differentiating, organizing comprehension (also condensation) of perceptions. It therefore has initially the character of a concept; without this it could not be experienced.

- Phenomenalism is a way of observation which does not go beyond merely finding and organizing (classifying, bringing into a system) of phenomena—that is, with tested rules and laws. The phenomena are thereby more outwardly accounted for within sterile categories (quantities) of space, time and movement.

Phenomenology on the other hand means to give a Logos, or meaning, to the phenomena. And that is not by way of taking recourse to metaphysics but through a free searching for coherent continuity. Thereby, not only the categories (quantities) which relate to measuring instructions, but all actually perceivable, through perceptions experiential qualities, are being worked. Open concepts are also included before they have saturated the experience through hasty definition. Only through this type of thinking can new questions arise and be put to the phenomena, and from the segmented observation which initially always prevailed, one moves away into the direction of a whole—not of the thing in itself, but of the width of interrelations.

Counter arguments

One could object that it is perfectly feasible to introduce the models in class 9 or earlier (furthermore, that one must do so—for the benefit of departing students), if only and at the same time one prevents them from turning into that ontological substitute of the world. I have tired to show in the first part of this article that in practice this can obviously not be achieved. For as soon as one deducts from the models conclusions that relate to specific facts, for the children they mean more than mere possibilities of combination. This "more" of course exists quite factually, but it can only be understood in the "right way," (i.e. non materialistically through quantum mechanics). An early introduction of the models today leads to the described misconception also because the popular scientific consciousness which of course forms nearly all spheres of life is deeply penetrated by it. The students are preprogrammed for the misconception! The wish to start with the models, particularly carefully but still earlier than what is held here, seems unreal because the young human being's thinking is not free but already occupied. Before anything else it needs to be made naturally impartial by a carefully aimed counter-move. The aim towards treating background questions of scientific method and model-based thinking first of all needs to build on a many-sided base of departure; one must, so to speak, catch up with and practice original and independent observation of nature. That is the most important task of the early years—extensive, time-consuming and with always new demands on the creativity of the teacher.

Also any subsequent radical questioning of the model-based view of nature hardly frees oneself from the latter (as I have tried to show). For the inner strength of a question, the motivation to bear its tension productively, springs from the strong connection with something that expresses itself in terms of "on the one hand—on the other hand"; it springs from becoming aware of one's own living within initially conflicting relations. If however one lives monotonously from childhood on within the "scientific world conception" described at the outset, then, it is true, one can question it at one stage or other, but such questioning will only become serious once one has also come to know, to experience, to consider the phenomena outside of the patterns of interpretation by the different branches of science. Even the best subsequent philosophical enquiry into the modern scientific method of acquiring knowledge surely cannot lead the student to seek in a way that is critical of the methods employed, unless another way of working, that is not yet so strongly reduced to quantitative and formally generalizing aspects, has actually been practiced for a number of years bearing fruit in the development of the student's thinking.

Final remark

It is the currently prevalent and encouraged motto of specialist teaching, particularly of chemistry, to see in the premature introduction and emphasis on model-based thinking a measure for the advancement and efficiency of every teaching methodology. The intention of our considerations is to point out that from a point of view from outside the particular technical specialty, e.g. in the eyes of the adult layman, this must appear questionable. It was shown that a concept differing greatly from the conventional, which arose out of Rudolf Steiner's theory of knowledge and out of developments of Waldorf education, is precisely not based on what one might fear after only initial contact:

1. that modern changes in the different branches of science and in didactics are being rejected;
2. that world conceptual presumptions flow as contents into lessons;
3. that a small student elite (Waldorf pupils) should be spared the coldness and somberness of contemporary natural science.

Much rather the endeavor is:

1. to build up in the first part of secondary school a true syllabus of a "comprehensive school" (without outer differentiation) that also includes the intellectually slow students and weak learners;
2. in the second part of secondary school to make fundamental use of the new concept of Beingness of modern physics, and not to work against such a concept in the previous stages;
3. to exercise various aspects of reality penetrating more deeply to the core of things, so that the students remain independent in the face of all world conceptions, in particular the "natural scientific worldview."

Insofar as some subject matter is sacrificed for a more general, philosophical aim, modern model-based theories are essential. For it is just these which demonstrate to the student more and more markedly the contrast, say, to phenomenological thinking. Only in this way can the recognition be won that scientific conceptualizations are a free human creation.